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Micromorphological and geochemical investigation of formation processes in the refectory at the castle of Margat (Qal'at al-Marqab), Syria

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A B S T R A C T

Margat Castle, located on the eastern coast of Syria, is an outstanding example of architecture from the Crusader Period, and the most important castle of the Hospitallers, who were one of the most famous Christian military orders during the medieval period. Excavations by the Syro-Hungarian Archaeological Mission have been conducted with the aim of better understanding the history and material culture of this important part of Syrian heritage. Whilst large scale excavation and architectural analysis can provide an understanding of broad changes over the lifetime of the monument, high resolution studies of deposits are essential to understand their formation processes, and to test hypotheses suggested during excavation. In the refectory at Margat, a series of dark deposits overlain by a pale 'ashy' layer, were hypothesised to be the result of a large-scale burning event. In this study we aimed to test this hypothesis by conducting micromorphological and geochemical analysis of the sequence, the first application of microarchaeological techniques to medieval deposits in Syria. It was observed that the composition of the deposits relates to degradation of anthropogenic debris and constructional material through cycles of wetting/drying and microbial and faunal activity, rather than fire/destruction debris. These observations have clarified important changes in the castles' function associated with multiple phases of ownership.

1. Introduction

Margat citadel, (Qal'at al-Marqab) is one of the most outstanding and best preserved monuments dating from the Crusader Period (1095–1291 AD), and was the most important castle of the Order of St John, otherwise known as the Knights Hospitaller (Fig. 1). The site is an important part of Syrian heritage reflecting the influence of several civilizations during its thousand year long history. The first castle is thought to have been built by the local inhabitants in the year H. 454 (1062/63 AD) (al-Hamawī nd). After a brief period of Byzantine occupation that began around 1104 (Comnena, 2003: 365 [1143–1153]), it was taken by the Franks (Crusaders) in 1117/18 AD, less than two decades after the capture of Jerusalem and the establishment of the crusader states in the Holy Land. The castle is thought to have reverted to Muslim ownership in the 1130s (Deschamps, 1973) and was recaptured by Renaud II Mazoir in 1140 (de Caschifelone, 1895). The Mazoirs were one of the highest-ranking baronial families in the Crusader principality of Antioch, and were responsible for building most of the earliest surviving structures at Margat. In 1187 AD, the Mazoirs transferred Margat to the Order of St. John (Mayer, 1993: 176, Delaville le Roulx, 1894–1906).

The importance of the castle to the Hospitallers is reflected in the fact that its acquisition resulted in the immediate reorganization of the regional administration (Riley-Smith, 1967: 431), and the Hospitaller castellan of Margat became one of the highest ranking officers in the hierarchy of the Order in the Latin East (Burgtorf, 2007: 222). Although it cannot be proven that the castle ever functioned as the seat of the Order between the fall of Jerusalem in 1187 AD and the retaking of Acre in 1191 AD (Abdazzāhir, 1961[1290]), the fact that the Chapter General of

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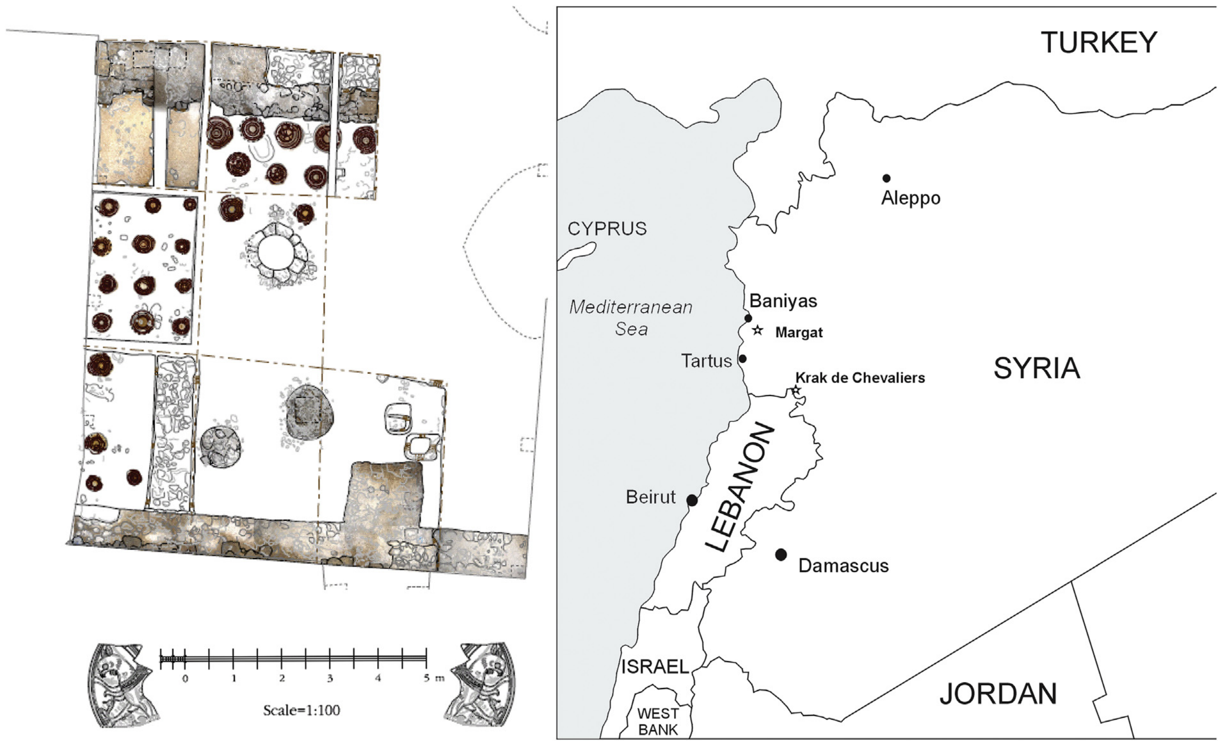

Fig. 1. Map showing the location of Margat and plan of the refectory. Plan produced by Ilona Györfy and József Vajda fotogrammeter@gmail.com.

1204/06 met there and established the rules that officially militarised the Hospitallers indicates its prestigious status.

By the beginning of the 13th century Margat had become the most important administrative centre of the Hospitallers in Syria and one of the largest fortified Crusader sites (Major, 2008). As well as the castle itself, Margat included an outer suburb that covered an estimated 10 ha of the western slopes of the mountain, and there were more than a thousand armed men employed for service, even during peacetime (De Sandoli, 1983). As was the case with other castle garrisons of the military orders, only a small part of the garrison belonged to the sergeants at arms who were the Hospitaller elite. However due to its prominent position amongst the Hospitaller hierarchy there are likely to have been a relatively high number of full members of the Order serving here, especially after the fall of the famous sister castle, Crac des Chevaliers in 1271 AD.

Margat was amongst the castles that resisted Muslim reconquest the longest, falling to the armies of the Mamluk Sultan Qalāwūn on 25 May 1285 after a five week siege (Abdazzāhir, 1961: 77–81). According to contemporary sources, the Sultan agreed to a peace offer to save the castle from further damage and the destruction caused by the siege was repaired immediately. After the expulsion of the Crusaders the castle began losing its importance, and although it is still mentioned until the 19th century as the administrative centre of the region, its diminishing role during the Mamluk and Ottoman periods is reflected in the reduced scale of building activity.

1.1. Environmental setting

Margat is located 360 m above sea level on the eastern coast of the Mediterranean Sea between Tartūs and Bānyās (Fig 1) in the coastal area of Jableh, part of the historic Principality of Antioch (Deschamps, 1973: 259–285). The surrounding area is composed mainly of limestone, with small outcrops of basalt, and the beach between Tartūs and Bānyās is composed of coarse grained basalt sand with large pebbles. The climate in the region is heavily influenced by the coastal setting and the Jabal Ansāriyya mountains, with annual precipitation being almost 500 mm higher around Latakia and Tartūs than inland. In the winter precipitation originates from the North Atlantic and Mediterranean Sea, whilst in summer subtropical high pressure systems inhibit rainfall except during thunderstorms (Kaniewski et al., 2011). During the Crusader Period (AD 1095–1291), the region was generally humid, following the relatively dry conditions in the Muslim Era (AD 640–1095). Local vegetation during the Crusader Period was dominated by mixed drought tolerant trees and xerophytic shrub steppe (Kaniewski et al., 2010).

1.2. The refectory

One of the main objectives of the Syro-Hungarian Archaeological Mission research programme was to identify the functions of the various constructions that made up the citadel. Another important question was whether the Muslim takeover modified the original functions in the spaces excavated and analysed. Given the presumably large size of the contingent of Hospitaller knights stationed at Margat and their monastic lifestyle, requiring a communal life that included shared meals, a hall of suitable size had to be located in the central part of the castle. Based on architectural analysis, this refectory hall has been identified as the great barrel vaulted hall situated in the western edge of the Hospitaller citadel overlooking the coast (Fig. 1), and was one of the first constructions erected in Hospitaller Margat. Being close to the chapter house, the dormitory and the chapel, the refectory hall was bordered in the north by a kitchen building with a chimney, where a central cooking area comprising of four ovens was excavated, and which had a southern doorway opening into the refectory. The refectory also had a large vaulted storage area beneath it, with two circular ventilation shafts making possible the elevation of barrels (presumably containing wine) with the help of pulleys. The hall was

also in close proximity of the central freshwater storage area of the citadel and the immediate vicinity had latrines located on three levels.

The interior area of the hall measures 25.6 × 9.5 m and is lit by a double row of windows from the West. This combined with the presence of a series of corbels in the sidewalls and the fact that the kitchen door opens at half the height of the northern wall of the hall makes it evident that the refectory was divided horizontally by a wooden mezzanine floor. The upper floor had its own doorway that could be reached by a wooden staircase from the neighbouring courtyard and it might have served as the refectory of the knights. The space beneath the wooden mezzanine floor might have been the dining area of the sergeant-at-arms, who were second in the Hospitaller hierarchy. The eastern wall of the lower area preserved a number of evenly arranged thin putlog holes, which indicate the presence of wooden shelves attached to the wall. The careful study of the corbels, combined with the results of the excavations which uncovered traces of the foundations on which the wooden pillars were standing, enabled a precise theoretical reconstruction of the wooden structure. Excavations directed by Zita Hrabák also found that during a later period, two lightly constructed division walls were inserted flanking the ground floor doorway, whilst the northern part of the ground floor room saw the insertion of dozens of huge earthenware storage jars into the clay floor. The jars were later destroyed and layers of "ashy" and black deposits covered them (Fig. 2, Table 1). As the Crusader Period refectory was characterized by the presence of huge wooden structures it would have been logical to assume that these layers might have been created by the destruction of the siege of 1285. This would also have meant that the construction of the partitioning walls and the insertion of the storage jars was the work of the Hospitallers. A detailed analysis of the layers was thus crucial not only for determining the origin of the layers, but was also expected to yield decisive information for the periodization of the building phases of the hall.

Understanding the formation processes of deposits is fundamental to understanding the archaeological record, and interpretation of human occupation and activity (Schiffer, 1987). These include both natural and anthropogenic processes and post-depositional impacts such as trampling, biological reworking, and diagenesis. Thin section micromorphology is a technique originally developed to study the formation processes of soils, and is now widely used in archaeology to examine the nature of stratigraphy that is too fine to see by eye (Matthews et al., 1997), and to identify the composition and mode of formation of materials whose origin may not be clear at the macroscale. It has been used extensively to investigate formation processes and activities at prehistoric sites (e.g. Shahack-Gross et al., 2005; Shillito et al., 2011), and has increasingly seen wider applications in historical and medieval archaeology (Devos et al., 2013; Milek, 2012; Novák et al., 2012).

The use of micromorphology has enabled a better understanding of the formation of floor deposits in medieval buildings (Gebhardt and Langohr, 1999), and the identification of post-depositional processes, which can have a significant impact on stratigraphy and preservation. Combining thin section micromorphology with chemical microanalysis (e.g. Milek and Roberts, 2013) provides information both on the micro context and the chemical composition, which greatly enhances interpretation of both formation processes and reconstruction of activities (Mentzer and Quade, 2013). There are several techniques available for analysing the geochemical composition of deposits, one of the simplest and most cost-effective is the use of infrared spectroscopy (FT-IR), which has been successfully combined with micromorphology to investigate for example, the mineral composition of calcareous ashy deposits (Shiegl et al., 1996, Karkanas et al., 2007), deposits associated with burning activities, and the makeup of floor deposits

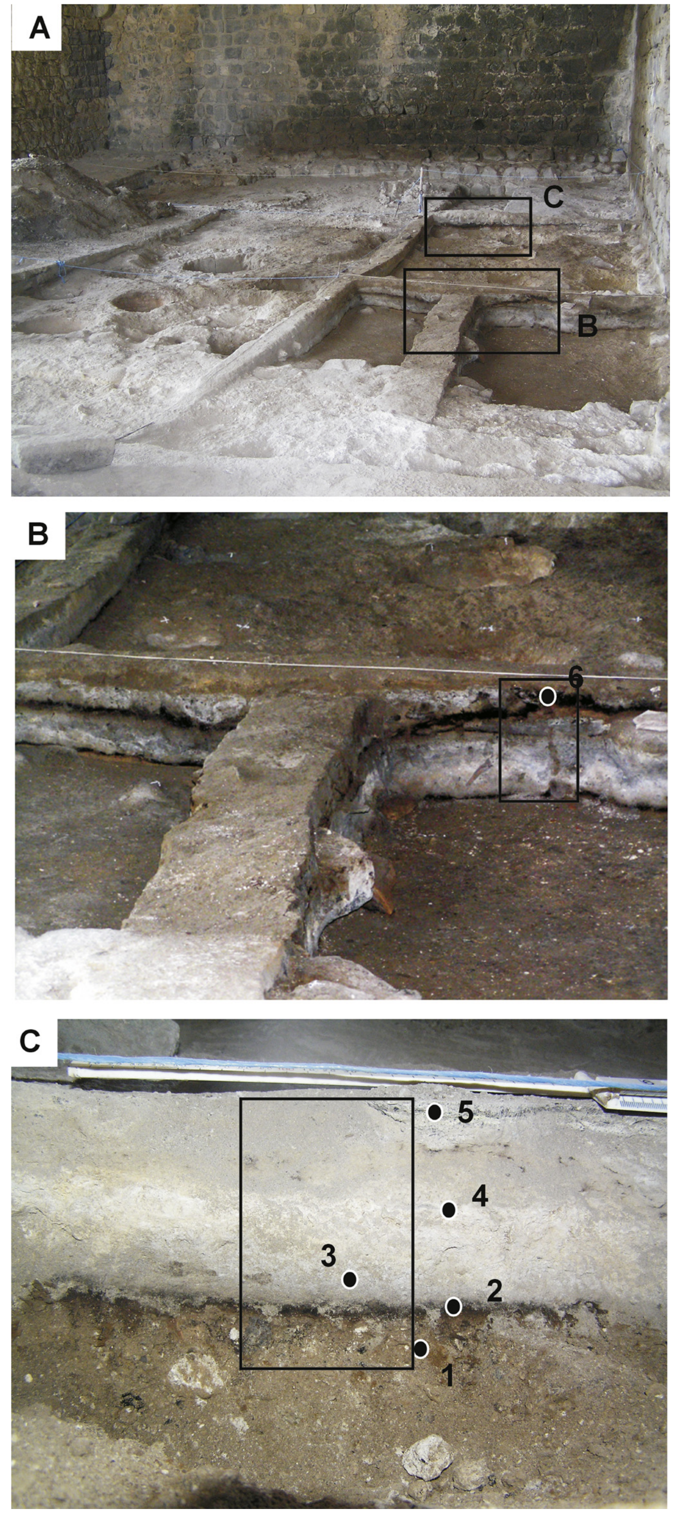

Fig. 2. A. view of the excavations in the refectory B. and C. detail of the deposits studied showing the location of bulk samples for geochemical analysis.

(Matthews et al., 2013). FT-IR is a type of vibrational spectroscopy which provides information on the chemical bonds present and the overall structural composition of the sample. X-Ray Diffraction (XRD) has perhaps been used to a lesser extent. It provides information of the specific atomic and molecular structure of a crystal, making it much more specific for identifying the types of minerals, including clays. The techniques are often used in combination in

Table 1
Peak assignments for the FT-IR spectra shown in in Fig. 4. Sub sample locations are shown in Fig. 2.

Sub sample number						Peak assignment	Major mineral/s responsible
1	2	3	4	5	6		
–	3699 (w)	–	–	3700 (w)	–	O–H stretch	Clay/plagioclase structural hydroxyl
–	3630 (w)	–	–	3623 (w)	–	O–H stretch	Clay/plagioclase structural hydroxyl
3407	3386	3407	3403	3396	3380	O–H stretch	Water/Hydroxyapatite/plagioclase structural hydroxyl
–	–	–	–	2514 (w)	–	Carbonate overtone/combinations	Calcite
1799 (w)	1796 (w)	1796 (w)	1796 (w)	1796 (w)	–	Carbonate overtone/combinations	Calcite
1625	1632	1635	1634	1635	1625	O–H bend	Water/plagioclase structural hydroxyl/gypsum h20
–	–	–	–	1416	1417	Carbonate stretch	Calcite/Aragonite
1422 (w)	1423(w)	1475–1423	1451–1422	–	–	Carbonate	Aragonite
1097 (w)	1092 (w)	–	–	–	–	S–O stretch	Gypsum/other sulphates
1122	1129	–	–	–	–	S–O stretch	Gypsum/other sulphates
–	–	1018	1012	1012	1019	Si–O–Si stretch/phosphate stretch	Clay (illite), apatite
917 (w)	914 (w)	–	–	914 (w)	–	Al–O–H bend	Clay (illite), plagioclase
876	876	874	872	872	873	Carbonate out-of plane-bend	Calcite/Dolomite
849	848	855	858 (w)	848	–	Carbonate out-of-plane bend	Aragonite
799/788	799	799/781 (w)	796/780 (w)	799/781 (w)	797/781 (w)	Si–O stretch	Quartz
713	713	713	715	712	713	Carbonate in-plane-bend	Calcite/Aragonite
672	–	–	–	687 (w)	–	Sulphate bend	Gypsum
603 (w)	603 (w)	603	603	–	602	Phosphate and/or sulphate bend	Apatite, gypsum
563 (w)	–	569	565	–	562	Phosphate bend	Apatite

FT-IR (w) = weak.

non-archaeological studies, including cultural heritage conservation, to characterise materials (Moroupoulou et al., 2000; Silva et al., 2005; Elsen, 2006).

These methods were therefore chosen as a suitable combination to characterise the sequence of deposits in the refectory and reconstruct their formation processes, in order to test whether they are the result of burning or another activity. Correct identification of such an activity has implications for understanding the history of this monument, an important part of the Syrian heritage.

2. Methods

2.1. Thin section micromorphology

Three large undisturbed block samples were collected for micromorphology by cutting directly from the section and wrapping securely with tissue and tape. Samples were collected to provide overlapping coverage of the entire exposed sequence of deposits (Fig. 2). The samples were oven dried and impregnated with epoxy resin under vacuum, and hardened overnight at 70 °C. 30 μm thin sections were prepared using Brot and Logitech thin sectioning machines. Thin sections were examined using a Leica DM750P polarising microscope under plane (PPL) and cross (XPL) polarised light with an integrated ICC50 HD camera. Descriptions were carried out according to the standard terminology of Stoops (2003).

2.2. FT-IR and XRD

Bulk samples for FT-IR and XRD were collected from selected layers visible in the field, adjacent to the block sample (Fig. 2). Around 1 g of the sub-samples were crushed in an agate pestle and mortar, oven dried to remove residual water and pressed into KBr discs. KKBr discs were analysed by FT-IR with a Perkin–Elmer Spectrum 100 FT-IR Spectrometer, and spectra obtained between 4000 and 400 cm^{-1} at 4 cm^{-1} resolution. FT-IR peak assignments were carried out by comparison with published reference material, including Weiner (2010) and Farmer (1974). Around 1 g of the sub-samples were analysed by XRD using a Bruker D8 Powder Diffractometer. XRD interpretations were carried out by comparison to the International centre for Diffraction Data (ICDD) reference library.

3. Results

3.1. Thin section micromorphology

Field observations of the deposits indicate a sequence comprising a thin lens of black material at the base of the sequence, overlain by a yellow/brown deposit containing occasional fragments of charcoal and grading into a darker brown deposit at the top. This is overlain by a compact, pale blue-grey deposit which grades into a whiter blue-grey, described as ‘ashy’ in the field. The top of the sequence comprises a very hard, compact grey deposit, with a second, discontinuous black layer containing mortar fragments. The black lenses vary in thickness across the room and were suggested to be charcoal and burnt debris layers. Under the microscope this sequence could be resolved in more detail. Micromorphology descriptions are summarised in Table 1.

The lowermost deposit of slide 1 (corresponding to the brown/black layer, Fig. 2C), has a diffuse boundary between paler and darker brown deposits, which consists of amorphous organo-mineral material containing fragments of limestone, lime mortar and basalt pebbles. This layer is bioturbated and features coatings, and 5–10% microcharocal and bone fragments (Fig. 3A). This is overlain by the ‘ashy’ deposits which similarly contains fragments of lime and basalt pebbles, along with fungal spores and mesofaunal pellets (Fig. 3B and C).

The lowermost ‘black’ deposit of slide 2 (roughly equal to the lowermost deposit of Slide 1) is a complex organo-mineral deposit, distinguished in thin section by its dark brown colour, and anthropogenic inclusions such as degraded bone (Fig. 3A) and charcoal ranging from 5 to 10% in abundance, and the presence of calcareous spherulites. The microstructure is vughy to massive, with chamber and channel voids present alongside vughs, resulting from the dissolution and subsequent welding of components (Stoops, 2003:65). Under XPL the fabric is largely undifferentiated, presumably due to the higher proportion of fine clays and brown amorphous organic material in the fine fabric. A faunal burrow c.20 mm in diameter can be seen at the macroscale, similar to those created by molluscs, and smaller channel voids are present at the microscale with internal coatings of infilled fine organic material produced by faunal excrement (Kooistra and Pulleman, 2010).

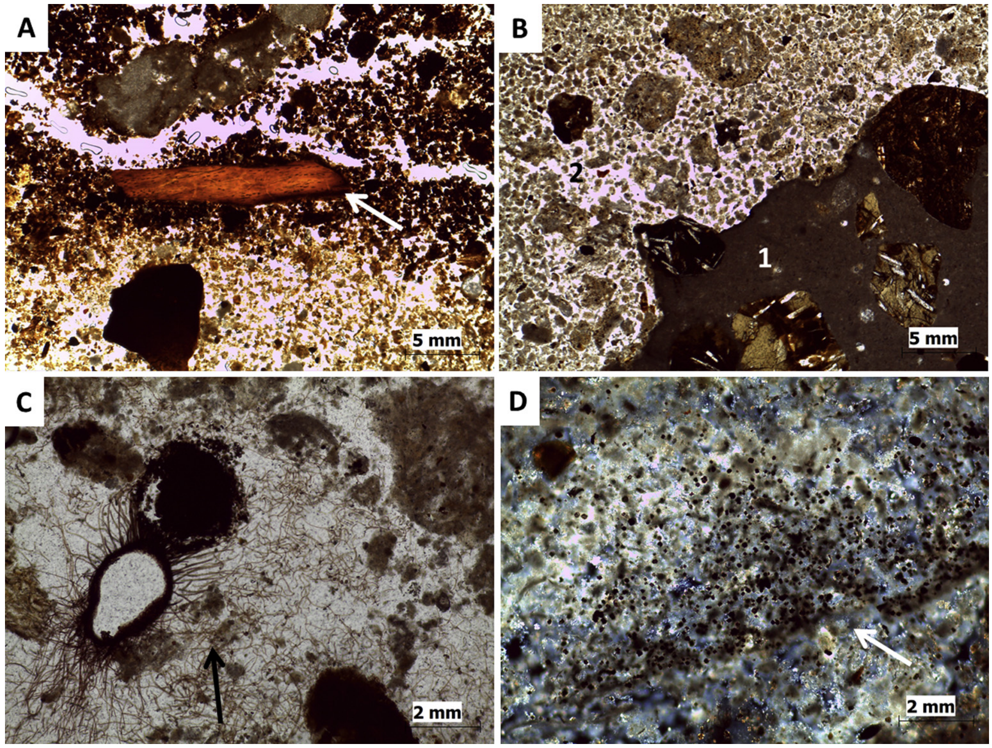

Fig. 3. Micrographs A. Sub unit 1b of slide 1 showing degraded burnt bone inclusion B. Sub unit 1c of slide 1 showing 1. Lime mortar fragment with embedded basalt pebbles and 2. Pellet structure of deposit from mesofaunal activity C. Sub unit 1c of slide 1 showing fungal masses and hyphae D. Sub unit 2c of slide 2 showing metal oxide staining.

The boundary with the overlying deposit is diffuse, with a gradual transition from this organo-mineral layer to a dense layer of amorphous organic material. This is identified as containing animal dung through the presence of distinct pellets embedded in the groundmass along with calcareous spherulites at 10–20% abundance. The b-fabric is a mix of undifferentiated and crystallitic, with some of the pellets being highly birefringent and blue in XPL. Mineral inclusions such as basalt are relatively low in abundance in this layer, at less than 5%, whilst organic inclusions such as phytoliths are present at around 5% abundance, embedded within the dung pellets and also the groundmass.

The boundary with the overlying yellow/brown unit is clear, especially at the macroscale, though at higher magnifications the transition is more diffuse. The unit is distinguished by a pronounced granular structure with packing voids, large channels and chambers. Animal dung pellets are present. It appears that this is a continuum of the underlying dung layer, which has been subject to a greater degree of post-depositional disturbance. Both deposits appear to be cemented together by the recrytallisation of calcareous material (Karkanas et al., 2007), which is distinct in XPL. Conjoined polyhedral phytoliths are present embedded within the deposits, and there is also significant iron and manganese staining (>20%) (Fig. 3D) associated with microbial activity (Tebo et al., 2004) and cycles of wetting and drying (Sveinbjarnardóttir et al., 2007; Lindbo et al., 2010:132). This is further supported by observation of fungal spores, areas of recrystallised ash and spherulitic siderite crystals within this layer and the underlying dung layer. Siderite forms in reducing conditions where there is an abundant source of iron in the soil (Milek, 2012).

The uppermost sub-unit consists of a fine fabric of amorphous particles with occasional mineral and aggregate inclusions, with a gefuric related distribution. Inclusions are unoriented and randomly distributed throughout the groundmass suggesting pre-depositional mixing rather than in situ deposition. Inclusions include fragments of lime, ranging in size from 300 μm to 1800 μm. Embedded within the larger lime fragments are inclusions of mineral grains and basalt pebbles, indicating that these are fragments of architectural mortar which have become incorporated into the deposit. Other inclusions include weathered monocotyledonous phytoliths and degraded microcharcoal (Fig. 3F). The hard compact uppermost deposit has a massive structure and consists of mortar fragments within a highly birefringent calcareous lime deposit. The mortar fragments contain basalt pebbles, some of which are completely weathered. Other pebbles have a thin yellow weathering rim.

3.2. FT-IR and XRD

The FT-IR spectra are shown in Fig. 4, the peak identification for FT-IR spectra are presented in Table 2. XRD identification is Table 3. The FT-IR spectra for all sub-samples are complex, relating to a mix of components including calcite, with varying amounts of phosphate and/or sulphate, clays, plagioclase and quartz. The strongest phosphate signal is in sub samples 2.3 and 2.4 (the 'ashy' layers) with a weaker signal in sub-samples 2.1 and 2.2 (the dark brown/yellow deposits). There are some features which are suggestive of sulphate, such as the weak broad peak around 1120 cm^{-1} however these are too weak to say this with certainty. It does however fit with observations of various sulphate compounds in thin section and in the XRD. Sub-sample 2.5 (the hard compact 'floor' layer) does not have a phosphate signal. There are weak peaks around 920 cm^{-1} suggesting the presence of clays. The presence of weak O–H stretches from structural hydroxyls, and O–H bends may result from plagioclase inclusions, which are also observed in thin section. Plagioclase signals are also seen in the powder XRD data for all sub samples. Illite formation has been associated with the weathering of plagioclase feldspar under semi-arid tropical climate conditions,

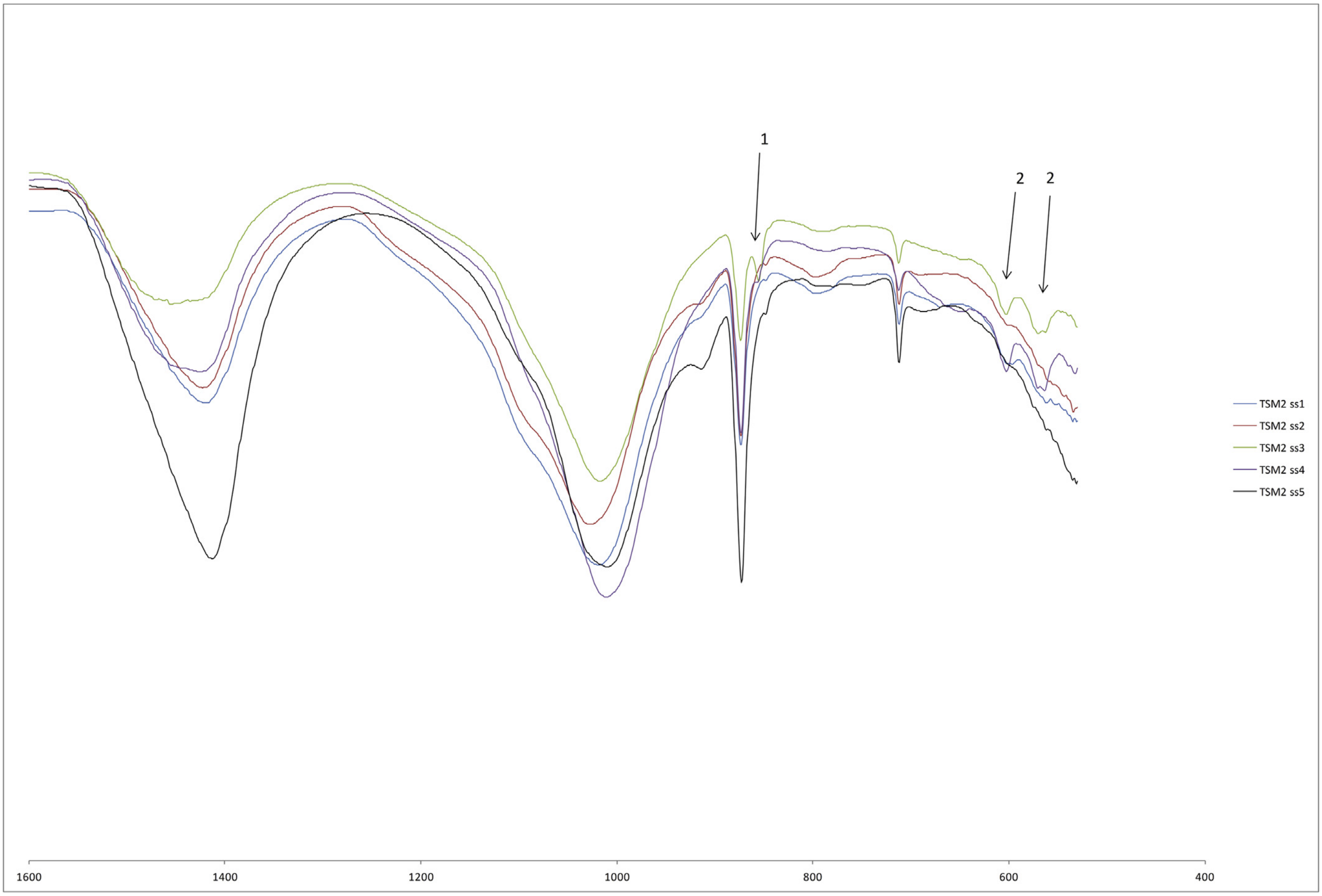

Fig. 4. FT-IR spectra of the bulk samples and detail of the 1600–400 region. Label 1 shows spilt peak indicating aragonite, label 2 indicates phosphate peaks.

and is perhaps the explanation for the presence of these peaks in the FT-IR spectra (Bétard et al., 2009).

The presence of biogenic aragonite in sub-samples 2.3 and 2.4 suggest the presence of shell, again corresponding with thin section observations, indicating degraded carbonate with shell fragments from the constructional debris. The uppermost deposit also contains halite and gypsum.

4. Discussion

Observation of the deposits under the microscope, along with their chemical analysis, indicates a basal deposit of amorphous organic material and clays mixed with anthropogenic debris. The presence of calcareous spherulites in addition to phosphate nodules and faunal pellets in thin section, and the presence of apatite in the FT-IR indicate animal dung deposits make up a proportion of the groundmass. The presence of micro-charcoal and degraded bone inclusions are likely to be the result of anthropogenic activities such as food processing and cooking, however the random orientation and distribution of these inclusions throughout the deposit do not indicate that this is a primary activity, rather it suggests that these waste materials were incorporated into the deposit during its formation.

The composition and structure of these deposits suggests either a packed earth ‘floor’ or levelling deposit. Mortar fragments are observed at a higher frequency towards the top of the sequence, and may relate to a finishing layer of lime and/or the wash of such material from the ceiling. The difference in colour from the darkest material in the lowermost deposits, which appear almost black in the field, and the overlying brown/yellow deposits, is a result of post-depositional decay and variation in oxidation (as indicated by fungal spores and significant microbial activity), with the boundaries between these deposits being diffuse under the microscope. The varying thickness of the lower ‘black’ layer therefore could be related to variations in the rate of decomposition across the room, or due to variations in the thickness of the original floor ‘packing’ to create an even surface, as has been observed in post-medieval floor deposits in Iceland (Sveinbjarnardóttir et al., 2007). The amorphous organic material may also relate to the decomposition of wood and would fit with our knowledge, based on architectural features, of the presence of a wooden mezzanine floor, and the hypothesis that the space beneath the wooden floor was reserved for the lower ranking sergeant at arms garrison.

Table 2
Summary of minerals identified using powder XRD. Sub sample numbers refer to locations shown in Fig. 2. Note that we were unable to obtain data for sub sample 1.

Sub sample/mineral	1	2	3	4	5	6
Apatite		*	*	*	–	*
Aragonite		–	*	*	–	–
Calcite		*	*	*	*	*
Gypsum		–	–	–	–	*
Halite		–	–	–	–	*
Plagioclase		*	*	*	*	*
Quartz		*	*	*	*	*

Table 3
Micromorphological descriptions. Position of slides shown on Fig. 2.

Slide/Sub unit	Ground-mass	Boundary	Sorting	Voids	Basic micro-structure	Inclusions				Post-depositional alterations and pedofeatures
						Rocks/minerals/aggregates		Bioarchaeological		
						1	2	1	2	
1C	c/f 70:30 coarse monic – close fine enaulic Crystallitic b fabric	Clear	Moderate	Complex packing, vughs, planar	Complex, granular–crumb	Basalt pebbles Foraminiferous limestone fragments Lime mortar fragments Plagioclase	<5% <5% <5% <5%	Occasional dung fragments Highly degraded bone fragments Fungal spores and hyphae	<10% <5% 5–10%	Smooth ellipsoidal microfaunal pellets Areas of Mn and Fe staining Calcite hypocoatings,
1B	c/f 70:30 Amorphous brown, undifferentiated, organo-mineral	Clear	Moderate	Complex packing, planar	Complex, granular–crumb	Angular to sub-rounded lime fragments Sub-angular to sub-rounded basalt pebbles	<5% 5%	Microcharcoal Burnt bone Shell fragments	<10% <5% <5%	Recrystallized carbonate nodules
1A	Large lime/calcareous fragments with embedded mineral inclusions	Diffuse	Unsorted	Cracking and chambers	Complex	Lime mortar fragments Basalt pebbles (embedded in lime) Foraminiferous limestone fragments	10% 10% 5%	Microcharcoal Degraded bone fragments	<5% <5%	Areas of bioturbation Calcite coatings
2E	c/f 10:90 gefuric >50%	Clear	Unsorted	Regular and star-shaped vughs, smooth.	Vughy	Sub-rounded to sub-angular lime fragments and mortar Rounded basalt pebble Amorphous phosphate	5–10% <5% <5%	Micro-charcoal Weathered monocot phytoliths Recrystallied ash rhombs	<5% 10%	Cracking Mesofaunal pellets
2D	c/f 10:90 Crystallitic to undifferentiated b-fabric	Clear	Unsorted	Regular and star-shaped vughs with chambers and channels, smooth	Vughy	Rounded basalt pebbles Amorphous phosphate	<5% <5%	Microcharocal Degraded burnt bone Calcareous spherulites Grass phytoliths	10% <5% <5% 5–10%	Crystalline coatings Mesofaunal pellets Spherulitic siderite nodules (iron carbonate)
2C	Granular Crystallitic b-fabric	Sharp	Unsorted	Complex packing with large channels and chambers	Complex, granular – crumb with vughy areas	Phosphate minerals	5%	Microcharocal Polyhedral conjoined phytoliths Animal dung pellets Calcareous spherulites	<5% <5% Clustered 10% 10–20%	Areas of metal oxide speckling from ? microbial activity
2B	Crystallitic to undifferentiated b-fabric	Clear	Unsorted	Regular and star-shaped vughs, pseudomorphic plant voids	Vughy	Rounded basalt pebbles	<5%	Layered animal dung pellets Calcareous spherulites Grass phytoliths Fungal spores and hyphae (globose warted)	10–20% 10–20% 5% <5%	Bands of metal oxide speckling from ? microbial activity Spherulitic siderite nodules (iron carbonate) Mesofaunal pellets Recrystallised ash
2A	Undifferentiated, organo-mineral matrix, highly variable	Clear	Unsorted	Occasional chambers, channels	Vughy	Rounded basalt pebbles with calcitic coatings Lime fragments Clay aggregates	<5% 5% <5%	Microcharoal Calcareous spherulites	<5% 10–20%	Mesofaunal burrowing (molluscs + insects)

Trampled dirt floors containing dung and other waste materials were not uncommon in medieval buildings, where they were constructed as part of a ground raising and/or levelling activity (Macphail and Goldberg, 2010). Macphail et al. (2007) for example identified a sequence of mortar floors overlain by trampled 'soil' in 10th century Ottonian church deposits within Magdeburg Cathedral precinct, Germany. Such floors did not always have a formal 'hard' finishing layer.

The presence of iron in the dark layers may be a result of the decomposition of metal objects, such as nails, which were observed during excavation, and also from the weathering of basalt. Iron sulphide formation is associated with anaerobic environments, where sulphate reducing bacteria may convert sulphates into hydrogen sulphide which can then form mineral deposits with iron or manganese, typically causing opaque black deposits. Subsequent exposure to oxygen leads to the formation of sulphuric acid, and the acidification creates the yellowish mineral jarosite. This process tends to occur in sediments with a high organic content that have been exposed to seawater or saline seepage (Huisman, 2009), which would fit with the identification of halite in the uppermost deposits. In the presence of lime we see the formation of gypsum instead, again fitting with the XRD data of the uppermost deposits. The presence of halite and gypsum in the uppermost layers indicates recent drying out of these upper layers leading to the precipitation of these salts, and is a further factor causing physical disaggregation of the floor. Recrystallised ash also suggests humid conditions and absorption of water by the ash deposits (Canti, 2003), which fits with our knowledge of the climate in this region and other features of the deposits.

The 'ashy' deposit is shown by FT-IR and XRD to consist of a mix of calcitic material with inclusions of plagioclase, aragonite and quartz. The calcitic material comprises degraded lime mortar, as well as fragments of limestone. Unlike Crak des Chevaliers, which is composed mainly of limestone (Kennedy, 1994), the primary building material at Margat is basalt. The plagioclase is likely to have its origin in the basalt pebbles which can be seen in thin section, and which are known to have been used in floor construction and can still be seen in well preserved floors in other parts of the castle. In the refectory it appears that the floor is much more poorly preserved, with both the underlying packing and mortar floor being highly degraded. Significant microbial and mesofaunal activity observed in the deposits and the fluctuating humidity in this region may be factors in the degradation process. Such degradation is supported by the pellet structure of the sediments, which is typical of sediments subjected to mesofaunal bioturbation. In effect what we are seeing is the formation of an underlying acid sulphate 'soil', which has reacted with the lime rich architectural materials to cause widespread degradation.

An interesting point is that the XRD and IR data do not match exactly, for example some of the samples show aragonite in the XRD but not in the FT-IR. This confirms the heterogeneity of the deposits and demonstrates the value in using a range of techniques to characterise the samples, and also suggests caution should be when using these techniques to characterise heterogeneous archaeological deposits. Bulk methods of FT-IR and XRD by themselves do not reveal the complexity and spatial variation of deposit composition. Higher resolution methods of characterising materials such as μ-XRF and IR are likely to prove more informative in future studies (Mentzer and Quade, 2013; Matthews et al., 2013).

The hypothesis suggested in the field can be rejected. The dark layers do not relate to a burning/destruction event, but instead deposits represent processes in the post Crusader Period, from remodelling of the floor followed by abandonment, and sporadic use as an animal pen. Similar field observations of floor deposits have been observed in the Medieval Motte of Werken, which were also suggested to be the result of possible charring of wooden floors, when in fact they were a result of decomposition under reducing conditions, identified by micromorphology (Gebhardt and Langohr, 1999).

5. Conclusions

The study gives an insight into the formation processes of deposits and the impacts of biological decay, and highlights the value of an integrated microarchaeological approach to reconstructing formation processes and interpreting stratigraphy within medieval buildings. During excavation it was hypothesised that the deposits in the refectory at Margat are a result of a sudden burning/destruction event. Whilst this hypothesis has been rejected, the alternative explanation is of equal importance. As the deposits include both animal dung and considerable quantities of mortar elements, presumably washed down from the plastered barrel vault and the walls by the leaking roofs, the results of this analysis point to the altered function and a long period of neglect in the history of the refectory hall. This makes it very probable that the wooden mezzanine floored refectory of the Hospitallers was remodelled by the Mamluks, who inserted the partitioning walls and the storage jars into the lower part of the refectory (Fig. 1), but very likely keeping the upper level of the hall with the mezzanine floor. The consequent reduction of the communal dining space was not an issue for the new owners who did not have the same rules and whose numbers were much lesser than that of the previous garrison, reflecting the fact that Margat was gradually losing its importance from the 14th century onwards. The insertion of storage jars in Crusader storage areas would have its parallels in the nearby Crac des Chevaliers and the recently excavated similar jars in the kitchen area of Margat might also possibly date from the same period. However these areas seem to have continued with a function quite close to their original ones. No precise date can be calculated at the moment for the time when the wooden mezzanine floor disappeared and the presumed Mamluk insertions were cleared away to make space for the animals whose presence the geoarchaeology has proved, but it seems to have taken place sometime in the Ottoman period.

The use of microstratigraphic analysis of occupation surfaces has not yet become routinely adopted in the study of archaeological contexts from medieval buildings, however its importance in clarifying changes in function associated with multiple phases of ownership of the same structures is clearly evident. In the case of the re-use of Frankish sites in the crusader states from the end of the thirteenth century by strikingly different cultures, adopting this approach to intact archaeological deposits advances current understandings beyond the focus on architectural modifications.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jas.2014.07.031.

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